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Models for predicting body dimensions needed for furniture design of junior secondary school one to two students.

[1]OladapoS.O,[2]AkanbiO.G
[1]*Department of Industrial and Production EngineeringUniversity of Ibadan, Nigeria.*
[2]*Department of Industrial and Production EngineeringUniversity of Ibadan, Nigeria.*

ABSTRACT

Purpose – The purpose of this study was to develop some models that will make use of easy-to-measure students' body dimensions to predict difficult, time-consuming and energy-sharping anthropometric dimensions needed for ergonomic school furniture design for junior secondary school one to two students.Design/methodology/approach – A total of 160 students aged 11 to 13 years were randomly selected from eight public secondary schools in Ogbomoso, South West Nigeria. All the dimensions were analyzed using Microsoft excel sheet 2010 and Design Expert version 6.0.8.The models with no/non-significant lack of fit and highest coefficient of determinations were selected as the best models for the required predictions.Findings – The study led to the development of 12 models that utilyzed easy-to-measure dimensions for estimating necessary anthropometric dimensions for the design of school furniture. The results of the study revealed that two-third of the anthropometric dimensions exhibited non-linear models.Originality/value – The furniture industry would find in these models economical, adequate and effective prediction tools.

KEY WORDS:*anthropometric dimensions, models, furniture industry.*

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I. INTRODUCTION

Furniture has an important role in the maintenance of good sitting posture. Using furniture that promotes proper posture is more important to children than adult because it is at this young age that sitting habits are formed (Reis et al., 2012). Bad sitting habits acquired in childhood and/or adolescence are very difficult to change later in adulthood (Yeats, 1997). Bad sitting habits are not unconnected with bad furniture design.Bad design of furniture may lead to health and learning problems. Therefore, design of furniture with proper dimensions is critical to encourage appropriate posture (Straker et al., 2010).

This necessitated the need for complete anthropometric data for each country (Garcia-Acosta and Lange-Morales, 2007) and based on anthropometric data obtained from the intended users, every country can design fitting furniture for school children (Molenbroek and Ramaekers, 1996; Oyewole et al., 2010) instead of a one-size-fits-all philosophy that has been adopted in the industry (Parcells et al., 1999; Adewole and Olorunnisola, 2010; Niekerk et al., 2013). This will require anthropometric data of the targeted population which are not ease-to-measure and time consuming. Furthermore, creating anthropometric databases usually requires considerable resources in terms of workforce, equipment, and funds.It is unlikely that the furniture industry will be able to rise to these challenges without better tools that can help it to achieve the desired furniture at minimum labour and time. Hence, the development of some models that will effectively make use of ease-to-measure dimensions to predict the difficult-to-measure ones needed for the design of school furniture is required.According to Ismaila et al., (2014), anthropometric regression models have been used in the development of ergonomic designs of various products and workstations. In fact, You and Ryu (2005) stated that most of the linear anthropometric regression models use only stature and/or weight to estimate body dimensions which resulted in unsatisfactory prediction for an anthropometric variable with low correlation (r) and low coefficient of determination (R^2).

Low coefficient of determination is an indication that the model is under fitted, that is, variable(s) that are really useful is/are not included in the model. This may be due to the fact that most researchers had concentrated on the economic reason while they had lost sight of adequacy and accuracy of the model. Therefore, the aim of this study was to develop some models that will make use of easy-to-measure students' body dimensions to predict difficult, time-consuming and energy-sharping anthropometric dimensions needed for ergonomic school furniture design.

II. METHODOLOGY

A total of 160 students (81 male, 79 female) of those who volunteered to participate in the study were randomly selected from junior secondary school one to two (J.S.S. 1-J.S.S. 2) in Ogbomoso, Oyo state Nigeria. They had no physical disabilities and had not participated in such previous study. Their age range is between 11 and 13years. The appropriateness of the sample size was verified using GPower 3.1 software version. The significant level and effect size that were used are 0.05 and 0.1 (small effect) respectively. The result of the analysis; sample size 160, number of predictors 4; returned a Power = 0.9753871. Since a power of 0.8 or greater is considered powerful conventionally, then the result of power analysis of 0.9999993 is adequately sufficient. However, if too many observations are used, even a trivial effect will be mistakenly detected as a significant one (High, 2000). By contrast, if too few observations are used, a hypothesis test will be weak and less convincing. Accordingly, there may be little chance to detect a meaningful effect even when it exists there. This led to a priori analysis to determine whether the sample size was actually not below or above the needed number of observation. A power of 95% was employed and the analysis returned a sample size of 132 as adequate. This justified the sample size of 160 used by the researchers as the resulted difference meant more power for the research. The demographic stratification parameter employed were levels in schools and gender. Jeong andPark (1990) had stated that Sex difference in anthropometry is significant for school furniture design. Measurements were carried out on the right-hand side of the participating students, to the nearest centimetre while the subjects were wearing light clothing and barefooted.The user's dimensions were taken and defined as presented below. They were taken with the use of anthropometer (Model 01290. Lafayette instrument company, Lafayette Indiana), tape measure, normal chair used by students in school, flat wooden pieces (used as foot rest to accommodate students of different heights) and a perpendicular wooden angle. The perpendicular wooden angle was used to fix the elbow at 90^0 as required for the measurements.

Stature (ST): Measured as vertical distance from floor to crown of head in standing position while the subject looks straight ahead.

Waist Height, Standing (WH): Measured as vertical distance from floor to the highest point on the waist in standing position.

Shoulder – grip Length (SL): Measured as horizontal distance from the shoulder to the tip of the longest finger in standing position.

Lower –arm length (LL): Measured as the horizontal distance from the elbow, when flexed at 90^0, to the tip of the longest finger in standing position.

Shoulder breadth (SB): Measured as the maximum horizontal distance across the shoulder in sitting position.

Knee Height (KH): Measured as vertical distance from the floor or footrest to the uppermost point on the knee in sitting position with knee flexed at 90^0.

Elbow Rest Height (EH): Measured as vertical distance from the sitting surface to the bottom of the right elbow while the elbow was flexed at 90^0 and shoulder was flexed at 0^0.

Popliteal Height (P): Measured as the vertical distance from the floor or the footrest to the underside of the thigh immediately behind the knee in the sitting position with knee flexed at 90^0.

Shoulder Height (SHH): Measured as the vertical distance from the sitting surface to the top of the shoulder at the acromion position.

Buttock-Popliteal Length (BPL): Measured as the horizontal distance from the rear surface of the buttock to the internal surface of the knee, or popliteal surface, with the knee flexed at 90^0.

Hip Width (HW): Measured as maximum horizontal distance across the hips in the sitting position.

The measurement was done thrice and the mean values were used as representing the true values. The measured data were analyzed using Microsoft excel sheet 2010 and Design Expert version 6.0.8. Descriptive statistics were reported (mean, minimum, maximum and 5th, 50th and 95th percentiles) to describe the anthropometric dimensions of subjects.

The dimensions were divided into dependent and independent variables. The dependent variables were the dimensions needed for school furniture design. This is because they are easy-to-measure and they are KH, EH, SHH, P, BPL and HW (Parcells, et al., 1999; Agha, et al., 2012). The independent variables were ST, WH, SL, LL, and SB because they are not easy-to-measure.Second order polynomial response surface model (equation twenty) was fitted to each of the response variable.

$$Y = \beta_\circ + \sum_{i=1}^{k} \beta_i x_i + \sum_{i<j}^{k} \beta_{ij} x_i x_j + \sum_{i=1}^{k} \beta_{ii}\, x_i^2 + \varepsilon \ldots\ldots\ldots\ldots\ldots (1)$$

Data were modeled by multiple regression analysis and the statistical significance of the terms was examined by analysis of variance for each response. The statistical analysis of the data and three dimensional plotting were performed using Design Expert Software (Stat-Ease 2002). The adequacy of regression model was checked by lack-of fit test, R^2, AdjR^2, Pre R^2, Adeq Precision and F-test (Montgomery 2001). The significance

of F value was judged at 95% confidence level. The regression coefficients were then used to make statistical calculation to generate three-dimensional plots from the regression model.

III. RESULTS.

The anthropometric dimensions of the students are presented in tables 1-2.

Table 1: The Mean, Minimum, Maximum and 5th, 50th And 95th Percentiles of J.S.S. 1-J.S.S. 2 Male for each Anthropometric Measurement (cm).

	Mean	Min	Max	5th Percentile	50th Percentile	95th Percentile
ST	147.47	132.80	174.00	135.50	145.90	162.30
WH	87.31	74.10	106.70	75.89	87.35	96.58
SL	67.55	56.40	82.00	60.00	67.00	75.50
LL	42.51	16.50	52.00	37.90	42.50	47.80
SB	25.60	18.10	44.90	20.60	25.60	29.50
KH	48.26	42.40	58.40	43.00	48.20	53.70
EH	16.06	8.20	21.00	12.20	16.20	19.40
P	39.02	33.00	47.30	35.00	38.80	44.10
SHH	45.16	36.30	54.70	39.20	44.80	52.10
BPL	42.62	31.60	51.00	37.30	43.00	49.00
HW	26.10	21.70	32.00	22.50	26.10	30.70

Table 2 The Mean, Minimum, Maximum and 5th, 50th And 95th Percentiles of J.S.S. 1-J.S.S. 2 Female for each Anthropometric Measurement (cm).

	Mean	Min	Max	5th Percentile	50th Percentile	95th Percentile
ST	152.93	134.00	170.80	142.62	153.40	164.05
WH	89.29	51.70	102.00	80.93	90.00	100.00
SL	70.39	58.70	92.80	64.00	70.00	78.26
LL	44.47	37.70	51.20	40.30	44.50	48.50
SB	26.12	20.10	33.90	22.18	26.20	30.17
KH	49.86	43.00	55.50	46.00	49.80	54.03
EH	17.10	12.00	22.00	13.10	17.00	20.11
P	40.10	34.00	45.10	36.45	40.00	44.25
SHH	47.79	42.00	57.00	42.60	47.50	53.50
BPL	45.98	39.80	51.60	42.07	45.60	50.21
HW	28.46	23.00	34.60	24.61	28.60	31.82

3.1 Models Presentation and Analysis for J.S.S.1-J.S.S.2 Male.

Data Analysis for Response 1: Knee Height

Quadratic model is suggested by the design program for this response to test for its adequacy and to describe its variation with independent variables. From ANOVA test in table 3, the Model F-value of 154.96 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Table 3: ANOVA test for KH

Source	Sum of squares	Df	Mean square	F value	P-value Prob> F	
Model	779.66	5	155.93	154.96	< 0.0001	Significant
A	59.43	1	59.43	59.06	< 0.0001	
B	9.847*10-5	1	9.847 *10-5	9.785 *10-5	0.9921	
A2	12.92	1	12.92	12.84	0.0006	
B2	6.50	1	6.50	6.46	0.0131	
AB	14.26	1	14.26	14.17	0.0003	
Residual	75.47	75	1.01			
Cor Total	855.13	80				

Values of "Prob> F" less than 0.0500 indicate model terms are significant. In this case A, A2, B2, and AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

The non-appearance of "Lack of Fit F-value" implies that the model perfectly (100%) fit relative to the pure error.

Table 4: Post ANOVA Statistics for KH

Std. Dev.	1.00		R-Squared	0.9117
Mean	48.42		Adj R-Squared	0.9059
C.V.	2.07		Pred R-Squared	0.8871
PRESS	96.59		Adeq Precision	56.780

From table 4, the "Pred R-Squared" of 0.8871 is in reasonable agreement with the "Adj R-Squared" of 0.9059. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 56.780 indicates an adequate signal. This model can be used to navigate the design space (Montgomery 2001).

In the same manner, other responses were analyzed and the resulted is presented in table 5.

Table 5: Design Summary for J.S.S.1-J.S.S.2 Male

Study type: response surface				Experiments: 232			
Initial design: historical data				Blocks: no blocks			
Design model: quadratic							
response	name	Units	obs	minimum	Maximum	trans	Model
Y1	KH	Cm	81	42.40	58.40	None	Quadratic
Y2	EH	Cm	81	15.04	18.17	None	Quadratic
Y3	P	Cm	81	33.00	46.02	None	Linear
Y4	SHH	Cm	81	39.58	53.15	None	Quadratic
Y5	BPL	Cm	81	37.30	49.82	None	Quadratic
Y6	HW	Cm	81	22.78	30.65	None	Quadratic

3.1.1 Model Equations for J.S.S.1-J.S.S.2 Male

Model equations are given in terms of coded factors and actual factors. Coded factors indicate when the minimum and maximum values of the factors are represented by -1 and +1 respectively instead of their actual values.

Response 1: Knee Height

The model in terms of coded factors is given by:

KH = +50.28 +7.52*A +0.010*B +5.64*A2 +3.88*B2 -10.02*A*B……. (2)

The model in terms of actual factors is given by:

KH = +16.92952 -1.08033*ST +2.54894*SL +0.018283*ST2 +0.023711*SL2 -0.038004*ST*SL……………………………………………… (3)

Response 2: Elbow Height

The model in terms of coded factors is given by:

EH = +16.62 +2.33*A -0.93*B +0.40*A2 +0.16*B2 -0.60*A*B………….. (4)

The model in terms of actual factors is given by:

EH = +6.91606 -0.016823*ST +0.13924*SL +9.34441*10-4*ST2 +9.74561*10-4*SL2 -2.26186*10-3*ST*SL …………………………………… (5)

Response 3: Popliteal Height

The model in terms of coded factors is given by:

P = +40.33 +3.33*A +3.09*B ………………………………………….………….. (6)

The model in terms of actual factors is given by:

P = -1.13642 +0.16147*ST +0.24131*SL ………………………………….. (7)

Response 4: Shoulder Height

The model in terms of coded factors is given by:

SHH = +47.36 +11.30*A -5.27*B +9.12*A2 +9.22*B2 -19.82*A*B…….. (8)

The model in terms of actual factors is given by:

SHH = -31.08688 -0.84157*ST +3.32834*SL +0.021482*ST2 +0.056273*SL2 -0.075152*ST*SL…………………………………………….. (9)

Response 5: Buttock Popliteal Length

The model in terms of coded factors is given by:

BPL = +44.06 +5.65*A +0.57*B +4.92*A2 +4.52*B2 -9.59*A*B………… (10)

The model in terms of actual factors is given by:

BPL = +17.82466 -0.76791*ST +1.80720*SL +0.011599*ST2 +0.027568*SL2 -0.036361*ST*SL……………………………………………. (11)

Response 6: Hip Width

The model in terms of coded factors is given by:

HW = +26.85 +2.24*A +1.62*B +1.01*A2 +1.14*B2 -2.11*A*B………. (12)

The model in terms of actual factors is given by:

HW = +6.36460 -0.072009*ST +0.38488*SL +2.38982*10-3*ST2 +6.98325*10-3*SL2 -7.98611*10-3*ST*SL …………………………………. (13)

3.1.2 Diagnostic Test-Normal Plots of Residuals and Predicted vs Actual Plots for J.S.S.1-J.S.S.2 Male

Normal plots of residuals and predicted vs actual Plots do show how precisely the responses are modeled. If all the points line up nicely and the deviation of points of the responses from normality is insignificant, then the model is a very good one.

Take KH for example, from figures 1-2 below, it is clearly observed that the developed models are very good models.

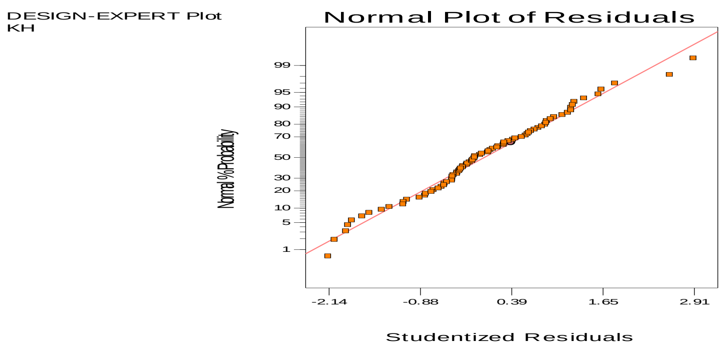

Figure 1: Normal plot of residuals for KH

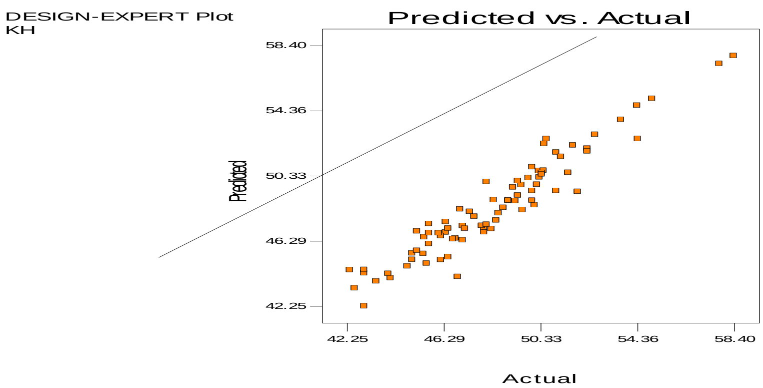

Figure 2: Predicted vs actual for KH

3.1.3 Response Surface Plots Analysis for J.S.S.1-J.S.S.2 Male

To aid visualization of variation in responses with respect to independent variables, series of three dimensional response surfaces were drawn using Design Expert Software (Stat-Ease 2002).

Response 1: Knee Height

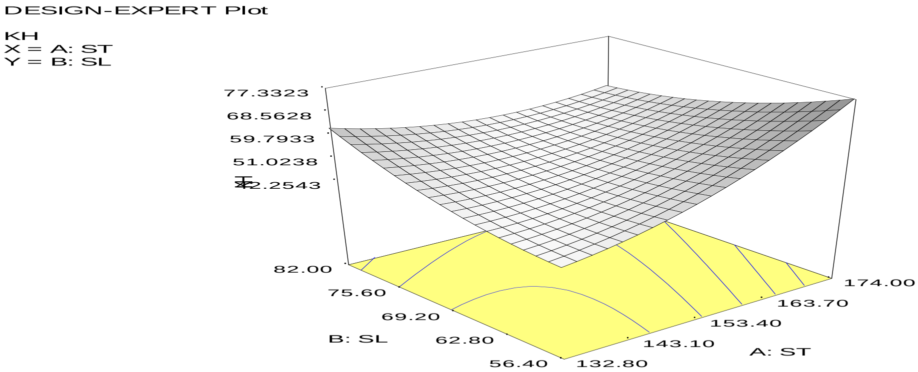

Figure 3: Response Surface Plots for KH

Figure 3 showed the interactive effect of ST and SL on the response (KH). At the low SL value of 56.400, KH increases from 42.25 to 51.90, as ST increases from 132.80 to 150.00. Furthermore, KH increases from 51.90 to 77.33, as ST increases from 150.00 to 174.00. This implied that KH increases as ST increases. Also, at high SL value of 82.00, KH decreases from 62.32 to 55.00, as ST increases from 132.80 to 167.50. Furthermore, KH increases form55.00 to 57.31, as ST increases from 167.50 to 174.00. This implied that KH decreases as ST increases and then KH increases slightly as ST further increases.

Response 2: Elbow Height

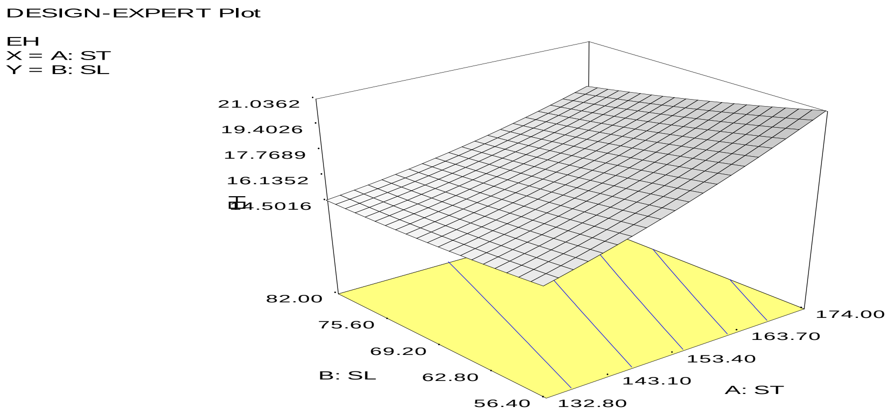

Figure 4: Response Surface Plots for EH

Figure 4 showed the interactive effect of ST and SL on the response (EH). At the low SL value of 56.400, EH increases from 15.17 to 15.66, as ST increases from 132.80 to 138.00. Furthermore, EH increases from 15.66 to 21.04, as ST increases from 138.00 to 174.00. This implied that KH increases as ST increases. Also, at high SL value of 82.00, EH increases from 14.50 to 17.15, as ST increases from 132.80 to 167.50. Furthermore, EH increases form17.15 to 17.98, as ST increases from 167.50 to 174.00. This implied that EH increases nearly linearly as ST increases.

Response 3: Popliteal Height

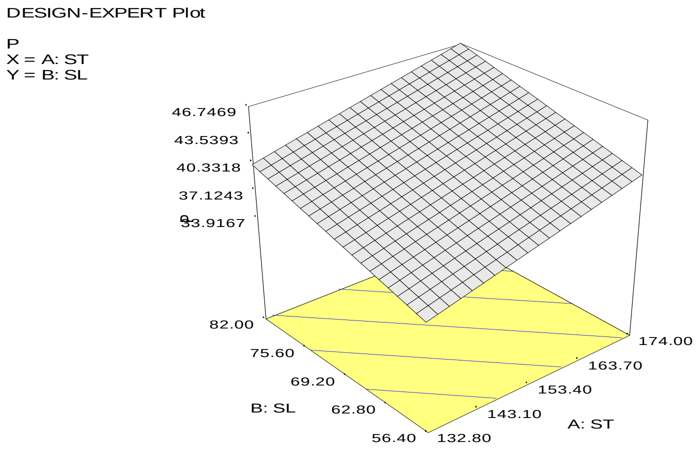

Figure 5: Response Surface Plots for P

Figure 5 showed the interactive effect of ST and SL on the response (P). At the low SL value of 56.400, P increases from 33.92 to 35.00, as ST increases from 132.80 to 140.00. Furthermore, P increases from 35.00 to 40.57, as ST increases from 140.00 to 174.00. This implied that P increases as ST increases. Also, at high SL value of 82.00, P increases from 40.09 to 46.00, as ST increases from 132.80 to 167.50. Furthermore, P increases from40.09 to 46.75, as ST increases from 167.50 to 174.00. This implied that P increases linearly as ST increases.

Response 4: Shoulder Height

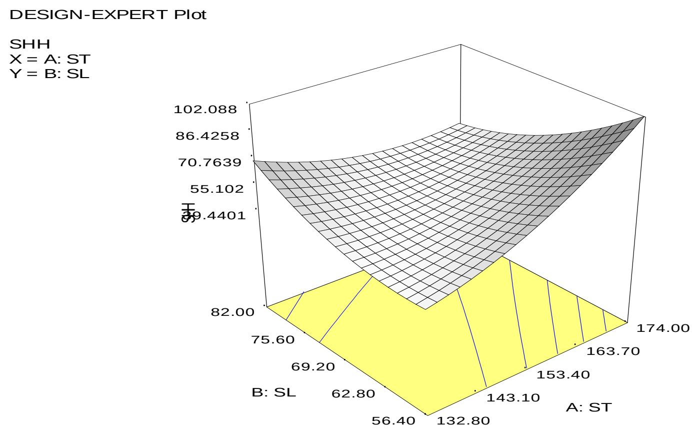

Figure 6: Response Surface Plots for SHH

Figure 6 showed the interactive effect of ST and SL on the response (SHH). At the low SL value of 56.400, SHH increases from 39.85 to 49.57, as ST increases from 132.80 to 141.85. Furthermore, SHH increases from 49.57 to 102.09, as ST increases from 141.85 to 174.00. This implied that SHH increases as ST increases. Also, at high SL value of 82.00, SHH decreases from 68.94 to 50.00, as ST increases from 132.80 to 167.50. Furthermore, SHH increases slightly from 50.00 to 51.91, as ST increases from 167.50 to 174.00. This implied that SHH decreases as ST increases and then KH increases slightly as ST further increases.

.Response 5: Buttock Popliteal Length

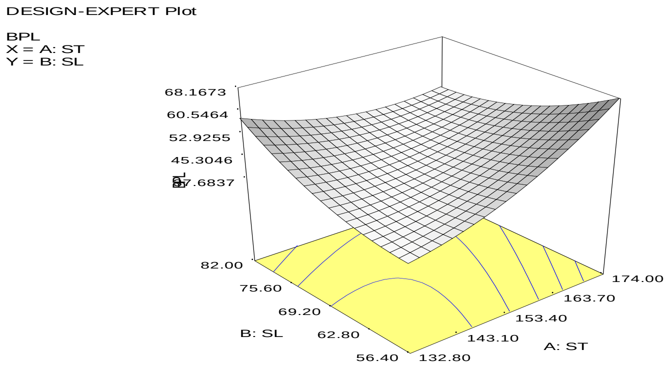

Figure 7: Response Surface Plots for BPL

Figure 7 showed the interactive effect of ST and SL on the response (BPL). At the low SL value of 56.400, BPL increases from 37.30 to 42.98, as ST increases from 132.80 to 145.90. Furthermore, SHH increases from 42.98 to 68.17, as ST increases from 145.90 to 174.00. This implied that SHH increases as ST increases. Also, at high SL value of 82.00, BPL decreases from 58.01 to 49.32, as ST increases from 132.80 to 167.50. Furthermore, BPL increases slightly from 49.32 to 49.82, as ST increases from 167.50 to 174.00. This implied that BPL decreases slightly as ST increases and then BPL increases slightly as ST further increases.

Response 6: Hip Width

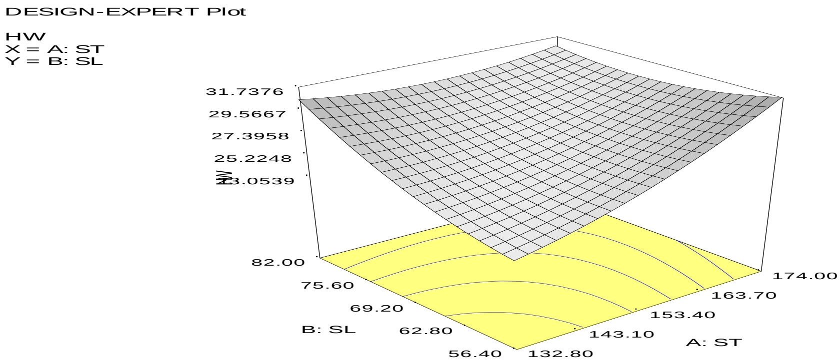

Figure 8: Response Surface Plots for HW

Figure 8 showed the interactive effect of ST and SL on the response (HW). At the low SL value of 56.400, HW increases from 23.05 to 27.83, as ST increases from 132.80 to 160.20. Furthermore, HW increases from 27.83 to 31.74, as ST increases from 160.20 to 174.00. This implied that HW increases as ST increases. Also, at high SL value of 82.00, HW slightly decreases from 30.50 to 29.98, as ST increases from 132.80 to 167.50. Furthermore, HW increases slightly from 29.98 to 30.65, as ST increases from 167.50 to 174.00. This implied that HW decreases slightly as ST increases and then BPL increases slightly as ST further increases.

3.2 Models Presentation and Analysis for J.S.S.1-J.S.S.2 Female

Data Analysis for Response 1: Knee Height

Linear model is suggested by the design program for this response to test for its adequacy and to describe its variation with independent variables. From ANOVA test in table 6, the Model F-value of 361.32 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Table 6: ANOVA test for KH

Source	Sum of squares	Df	Mean square	F value	P-valueProb> F	
Model	423.59	2	211.80	361.32	< 0.0001	Significant
A	374.32	1	374.32	638.59	< 0.0001	
B	3.32	1	3.32	5.67	<0.0198	
Residual	44.55	76	0.59			
Lack of fit	44.37	75	0.59	3.29	< 0.4171	Not Significant
Pure Error	0.18	1	0.18			
Cor Total	468.14	78				

Values of "Prob> F" less than 0.0500 indicate model terms are significant. In this case A and B are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

"Lack of Fit F-value" of 3.29 implies the Lack of Fit is not significant relative to the pure error. There is a 41.74% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good-we want the model to fit.

Table 7: Post ANOVA Statistics for KH

Std. Dev.	0.77		R-Squared	0.9048
Mean	49.85		Adj R-Squared	0.9023
C.V.	1.54		Pred R-Squared	0.8964
PRESS	48.48		Adeq Precision	76.689

From table 7, the "Pred R-Squared" of 0.8964 is in reasonable agreement with the "Adj R-Squared" of 0.9023. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 76.689 indicates an adequate signal. This model can be used to navigate the design space (Montgomery 2001).

In the same manner, other responses were analyzed and the resulted is presented in table 9.

3.2.1 Model Equations for J.S.S.1-J.S.S.2 Female

Model equations are given in terms of coded factors and actual factors. Coded factors indicate when the minimum and maximum values of the factors are represented by -1 and +1 respectively instead of their actual values.

Response 1: Knee Height

The model in terms of coded factors is given by:

KH = +49.61 +6.02*A -0.59*B ……………………………………….…………. (14)

The model in terms of actual factors is given by:

KH = +2.10855 +0.32691*ST -0.086038*SB.……………………………. (15)

Response 2: Elbow Height

The model in terms of coded factors is given by:

EH = +17.57 +0.48*A +0.98*B -0.21*A2 +0.10*B2 -1.91*A*B………… (16)

The model in terms of actual factors is given by:

EH = -67.83578 +0.61795*ST +2.54982*SB -6.107*10-4*ST2 -2.14380*10-3*SB2 -0.015036*ST*SB ………………………………………. (17)

Response 3: Popliteal Height

The model in terms of coded factors is given by:

P = +39.74 +5.28*A -1.58*B ……………………………………….…………. (18)

The model in terms of actual factors is given by:

P = +2.18285 +0.28695*ST -0.22858*SB ………………………………… (19)

Response 4: Shoulder Height

The model in terms of coded factors is given by:

SHH = +47.18 +6.54*A -2.54*B ……………………………………..………. (20)

The model in terms of actual factors is given by:

SHH = +2.93934 +0.35557*ST -0.36839*SB ..…………………........... (21)

Response 5: Buttock Popliteal Length

The model in terms of coded factors is given by:

BPL = +45.83 +4.89*A -0.52*B -0.094*A*B ……………….…………… (22)

The model in terms of actual factors is given by:

BPL = +4.30094 +0.28584*ST +0.037282*SB -7.37656*10-4*ST*SB……………………………………………………………………………… (23)

Response 6: Hip Width

The model in terms of coded factors is given by:

HW = +28.51 +2.62*A +2.03*B -1.16*A2 +3.30*B2 -3.01*A*B………. (24)

The model in terms of actual factors is given by:

HW = -127.81789 +1.82960*ST +0.15394*SB -3.43837*10-3*ST2 +0.069408*SB2 -0.023671*ST*SB …………..………………………………. (25)

3.2.2 Diagnostic Test-Normal Plots of Residuals and Predicted vs Actual Plots for J.S.S.1-J.S.S.2 Female

Normal plots of residuals and predicted vs actual Plots do show how precisely the responses are modeled. If all the points line up nicely and the deviation of points of the responses from normality is insignificant, then the model is a very good one.

Take EH for example, from figures 9-10 below, it is clearly seen that the developed models are very good models.

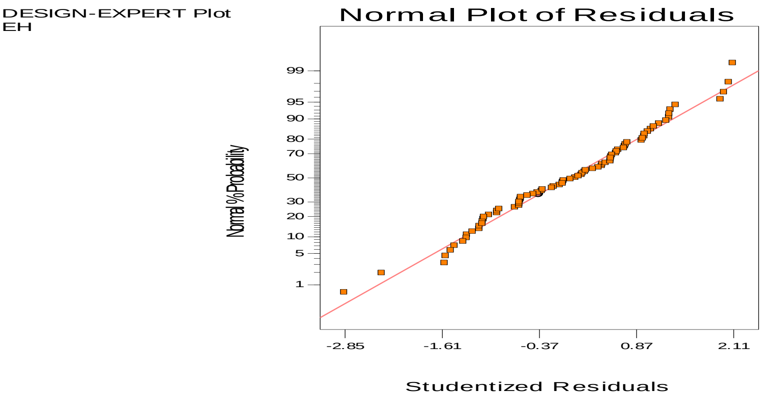

Figure 9: Normal plot of residuals for EH

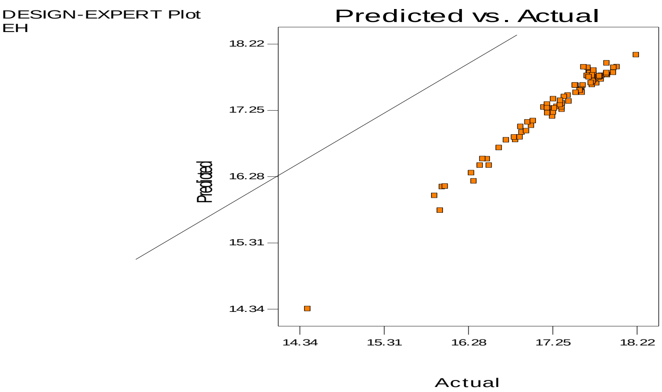

Figure 10: Predicted vs actual for EH

3.2.3 Response Surface Plots Analysis for J.S.S.1-J.S.S.2 Female

To aid visualization of variation in responses with respect to independent variables, series of three dimensional response surfaces were drawn using Design Expert Software (Stat-Ease 2002).

Response 1: Knee Height

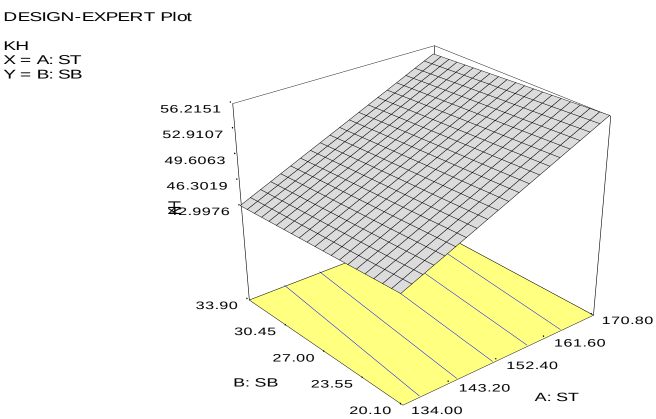

Figure 11: Response Surface Plots for KH

Figure 11showed the interactive effect of ST and SB on the response (KH). At the low SB value of 20.10, KH decreases from 44.18 to 43.40, as ST increases from 134.00 to 137.00. Furthermore, KH increases from 43.40 to 56.22, as ST increases from 137.00 to 170.80. This implied that KH decreases slightly as ST increases and later increases as ST increases. The relationship is a linear one. Also, at high SB value of 33.9, KH increases from 43.00 to 49.94, as ST increases from 134.00 to 155.30. Furthermore, KH increases from 49.94 to 55.03, as ST increases from 155.30 to 170.80. This implied that KH increases as ST increases in a linear relationship.

Response 2: Elbow Height

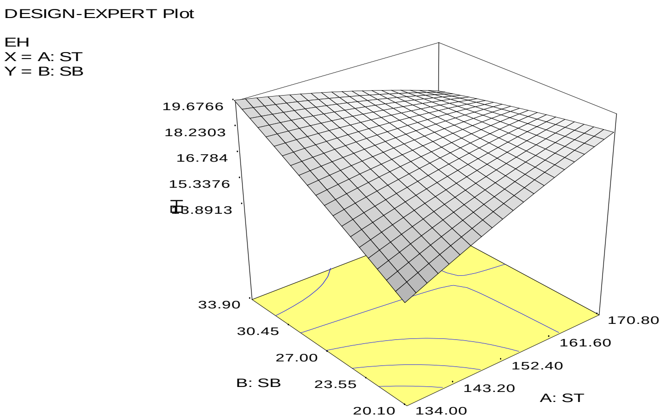

Figure 12: Response Surface Plots for EH

Figure 12 showed the interactive effect of ST and SB on the response (EH). At the low SB value of 20.10, EH increases slightly from 13.89 to 14.44, as ST increases from 134.00 to 137.00. Furthermore, EH increases from 14.44 to 18.66, as ST increases from 137.00 to 170.80. This implied that KH increases as ST increases. Also, at high SB value of 33.90, EH decreases from 19.68 to 18.22, as ST increases from 134.00 to 155.30. Furthermore, EH decreases form18.22 to 16.81, as ST increases from 155.30 to 170.80. This implied that EH decreases as ST increases.

Response 3: Popliteal Height

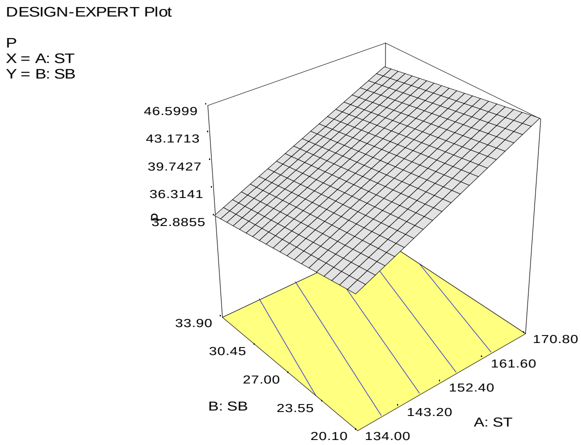

Figure 13: Response Surface Plots for P

Figure 13 showed the interactive effect of ST and SB on the response (P). At the low SB value of 20.10, P increases slightly from 36.04 to 36.54, as ST increases from 134.00 to 137.00. Furthermore, P increases from 36.54 to 46.60, as ST increases from 137.00 to 170.80. This implied that P increases linearly as ST increases. Also, at high SB value of 33.90, P increases from 32.89 to 38.30, as ST increases from 134.00 to 153.60. Furthermore, P increases from 38.30 to 43.45, as ST increases from 153.60 to 170.80. This implied that P increases linearly as ST increases.

Response 4: Shoulder Height

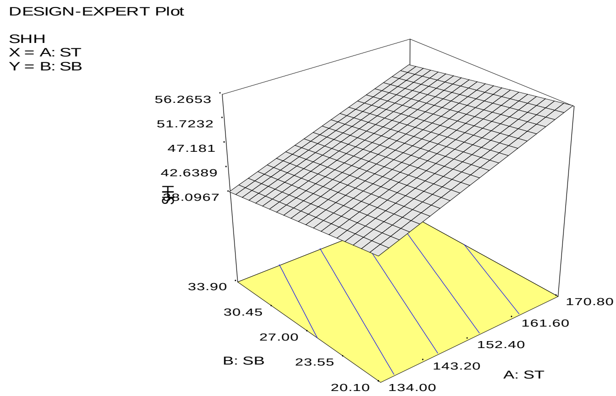

Figure 14: Response Surface Plots for SHH

Figure 14 showed the interactive effect of ST and SB on the response (SHH). At the low SB value of 20.10, SHH increases slightly from 43.18 to 44.20, as ST increases from 134.00 to 137.00. Furthermore, SHH increases from 44.20 to 56.27, as ST increases from 137.00 to 170.80. This implied that SHH increases as ST increases in a linear manner. Also, at high SB value of 33.90, SHH decreases from 38.10 to 51.18, as ST increases from 134.00 to 170.80. The relationship is linear.

Response 5: Buttock Popliteal Length

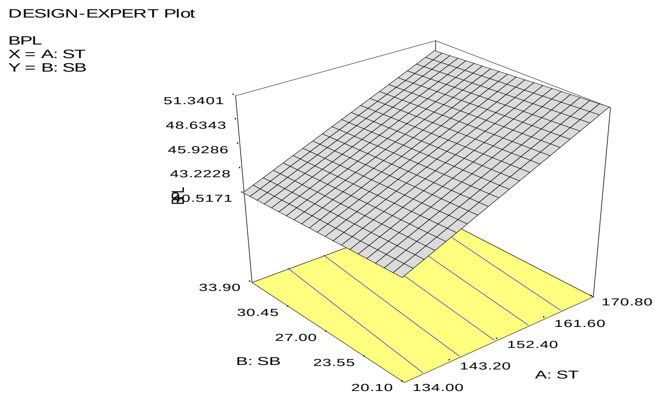

Figure 15: Response Surface Plots for BPL

Figure 15 showed the interactive effect of ST and SB on the response (BPL). At the low SB value of 20.10, BPL increases slightly from 41.37 to 42.12, as ST increases from 134.00 to 137.00. Furthermore, BPL increases from 42.12 to 51.34, as ST increases from 137.00 to 170.80. This implied that SHH increases as ST increases. Also, at high SB value of 33.90, BPL increases from 40.52 to 47.92, as ST increases from 134.00 to 161.80. Furthermore, BPL increases slightly from 47.92 to 50.07, as ST increases from 161.80 to 170.80. This implied that BPL increases as ST increases and then BPL increases slightly as ST further increases.

Response 6: Hip Width

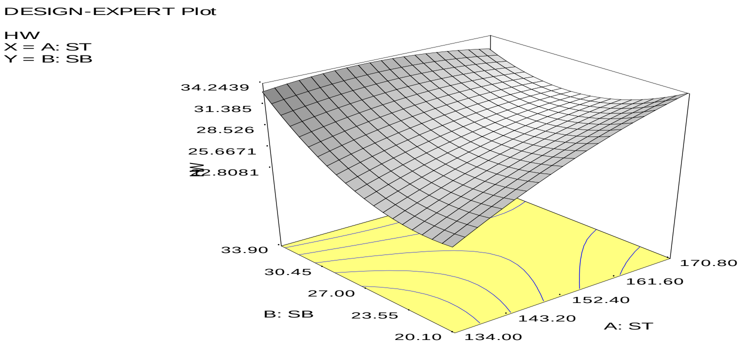

Figure 16: Response Surface Plots for HW

Figure 16 showed the interactive effect of ST and SB on the response (HW). At the low SB value of 20.10, HW increases slightly from 22.99 to 24.49, as ST increases from 134.00 to 137.00. Furthermore, HW increases from 24.49 to 34.24, as ST increases from 137.00 to 170.80. This implied that HW increases as ST increases. Also, at high SB value of 33.90, HW slightly decreases from 33.07 to 33.00 as ST increases from 132.80 to 170.80. This implied that HW decreases slightly as ST increases.

Table 8: Design Summary for J.S.S.1-J.S.S.2 Female

Study type: response surface				Experiments: 231			
Initial design: historical data				Blocks: no blocks			
Design model: quadratic							
response	name	Units	obs	minimum	Maximum	trans	Model
Y1	KH	Cm	79	43.40	55.50	None	Linear
Y2	EH	Cm	79	14.44	18.22	None	Quadratic
Y3	P	Cm	79	34.77	44.77	None	Linear
Y4	SHH	Cm	79	41.26	53.29	None	Linear
Y5	BPL	Cm	79	40.96	50.41	None	2FI
Y6	HW	Cm	79	23.88	32.08	None	Quadratic

It is worthy of note that two independent variables sufficiently predicted the entire six responses in this category of students (J.S.S.1-J.S.S.2 male and female). This may not be unconnected with the fact that students in lower classes had small physique unlike their counterparts in middle and upper classes with well-built physique.

Table 9: Summary of Co-efficient of Determination (R2) and Co-efficient of Variation (C.V.) of all the Responses for J.S.S.1-J.S.S.2 Male/ J.S.S.1-J.S.S.2 Female.

Response	R-Square	Adj. R-Square	Pred. R-Square	C.V (%)
	Male/Female	Male/Female	Male/Female	Male/Female
KH	0.9117/0.9048	0.9059/0.9023	0.8871/0.8964	2.07/1.54
EH	0.9939/0.9789	0.9935/0.9774	0.9925/0.9719	0.34/0.54
P	0.8843/0.9077	0.8813/0.9053	0.8758/0.9024	2.40/1.57
SHH	0.9979/0.9983	0.9977/0.9982	0.9969/0.9981	0.32/0.21
BPL	0.9531/0.9986	0.9499/0.9986	0.9364/0.9984	1.40/0.16
HW	0.9932/0.9952	0.9928/0.9949	0.9874/0.9930	0.51/0.41

IV. DISCUSSIONS

4.1 Efficiencies of the Models.

The most common performance measures for the efficiency of predictive models are co-efficient of determination (R^2) and co-efficient of variation (C.V) (Agha, et al., 2012). High value of R^2 and low value of C.V are desirable. In this study, twelve models were developed and the adjusted co-efficient of determination (R^2) is greater than 0.85 in all.In general, all the models showed good predictive ability (efficiency) as can be observed in Table 9. 75% of the models have adjusted R^2 value of over 90% and non-of the models have adjusted R^2 value that is less than 85%. This confirmed the validity of the models.Furthermore, according to Liyana-Pathirana and Shahidi (2005), a high coefficient of variation (CV) demonstrates that variation in the mean value is large and does not sufficiently generate an acceptable response model. Therefore, CV < 10% has been suggested suitable in predicting the response surface models. From table 6, CV <= 2.40% for all the models. This implied that the models exhibited very high predictive ability (they are efficient).

4.2 Discussions of the Models.

Using ergonomic principles, the common anthropometric measurements considered in the design of furniture are popliteal height for seat height,buttock-popliteal length for seat depth, hip breadth for seat width, shoulder height for backrest height, elbow height for table height, and knee height for underneath desk height. The current study developed 12 models considered necessary for the design of furniture for J.S.S.1-J.S.S.2 students. While the relationships among standing height and length dimensions have usually been assumed linear, the present study confirmed that Out of the 12 models developed, 8 of them have non-linear relationships (representing 66.67%). Only 4 models (representing 33.33%) have linear relationships.Moreover, the present study obtained a higher value of R^2 which is 0.8813 and0.9953 compared with R^2_ 0.81 (r _ 0.90) obtained by Castellucciet al. (2010) and 0.844 obtained by Ismaila et al., (2014) for the model for predicting popliteal height. Also, the value of R^2 for EH in the present study is 0.9774 and 0.9935 which is far higher than 0.264 obtained by Agha et al., (2012) and 0.706 obtained by Ismaila et al., (2014). Indeed, Agha et al., (2012) reported that EH cannot be predicted but rather measured. However, the present study showed otherwise. The performance of the models developed in this study as compared with the previous ones is presented in table 10.

Table 10: Performance Comparism of the Developed Models with those of Previous Researches.

Anthropometric dimensions	R^2 obtained in this study Min.-Max.	R^2 obtained by Castellucci et al., (2012).	R^2 obtained by Ismaila et al., (2014).
KH	0.9023-0.9059	0.921	0.725
EH	0.9774-0.9935	0.264	0.706
P	0.8813-0.9053	O.721	0.844
SHH	0.9977-0.9982	0.755	0.414
BPL	0.9499-0.9986	0.753	0.416
HW	0.9928-0.9949	Not applicable	0.199

According to Ismaila et al., (2014), it can be very expensive in developing countries to obtain anthropometric data when needed, and as such, measuring one anthropometric value to determine others would be helpful and affordable. Although economic reason is important but, at the same time, adequacy and effectiveness of the predictive models cannot be compromised. The current study took these three factors (economic reason, adequacy and effectiveness) into consideration. Using two anthropometric dimensions to predict six needed for the design of school furniture, as the case is for students in J.S.S.1-J.S.S.2, is justifiable in view of the high predictive ability of the models.

V. CONCLUSION

Ergonomic design of products and workplaces demands up-to-date anthropometric data which are not readily available. In fact most practitioners do not know how the data for easily measured body dimensions can be used to estimate body dimensions that are more difficult to measure. The present study, therefore, proposed 12 models that can be used to estimate various anthropometric dimensions necessary for the design of furniture for use ofJ.S.S.1-J.S.S.2 students in Ogbomoso, South Western Nigeria. The furniture industry would find in these models economical, adequate and effective prediction tools.

REFERENCES

[1] Adewole, N.A., Olorunnisola, A.O., (2010), “Characteristics of classroom chairs and desks in use in senior secondary schools in Ibadan, Oyo State, Nigeria”, Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), Vol. 1 No. 2, pp 140-144.

[2] Agha, S.R., Alnahhal, M.J., (2012), “Neural Network and multiple linear regressions to predict school children dimensions for Ergonomic school furniture design”, Applied Ergonomics, Vol. 43, pp 979-984.

[3] Garcia – Acosta, G., Lange-Morales, K., (2007), “Definition of sizes for the design of school furniture for Bogota schools based on anthropometric criteria”, Ergonomics, Vol. 50 No. l0, pp 1626–1642.

[4] Ismaila, S.O., Akanbi, O.G., Ngassa, C.N. (2014), "Models for estimating the anthropometric dimensions using standing height for furniture design", Journal of Engineering, Design and Technology, Vol. 12 No. 3, pp. 336-347.

[5] Jeong, B.Y., Park,K.S. (1990), “Sex difference in Anthropometry for school furniture design”, Ergonomics, Vol. 33 No. 12, pp 1511-1521.

[6] Liyana-Pathirana, C., Shahidi, F. (2005), “Optimization of extraction of phenolic compounds from wheat using response surface methodology”, Food Chem., Vol.93, pp 47-56.

[7] Molenbroek, J., Ramaekers, Y. (1996), “Anthropometric design of a size system for school furniture”, In: Robertson, S.A. (Ed.) 1996 Proceedings of the Annual Conference of the Ergonomics Society: Contemporary Ergonomics, 1996, Taylor and Francis, London, pp. 130–135.

[8] Niekerk, S., Louw, Q.A., Grimmer-Somers,K., Harvey, J. (2013), “The anthropometric match between high school learners of the caps metropolitan area, Western cape, South Africa and their computer Workstation at school”, Applied Ergonomics, Vol. 44 No. 3, pp 366-371.

[9] Oyewole, S.A., Haight, J.M., Freivalds, A., (2010), “The ergonomic design of classroom furniture/computer work station for first graders in the elementary school”, International Journal of Industrial Ergonomics, Vol. 40 No. 4, pp 437 – 447.

[10] Parcells, C., Manfred,S., Hubbard, R.(1999), “Mismatch of classroom furniture and body dimensions, Empirical findings and health implications”, Journal of Adolescent Health, Vol. 24 No. 4, pp 265-273.

[11] Reis, P., Moro, A.R., Da, S.J., Paschoarelli, L. Nunes, S.F., Peres, L. (2012), “Anthropometric aspects of body seated in school”. Work, Vol. 41, pp 907-914. DOI: 10.3233/WOR-2012-0262-907.

[12] Straker, L., Maslen, B., Burgress-Limerick, R., Johnson, P., Dennerlein, J. (2010), “Evidence-based guideline for wise use of computers by children: physical development guidelines”, Ergonomics, Vol. 53 No. 4, pp458-477.

[13] Yeats, B. (1997), “Factors that may influence the postural health of schoolchildren (K-12)”, Work: A Journal of Prevention, Assessment and Rehabilitation, Vol. 9, pp 45–55.

[14] You, H., Ryu, T. (2005), “Development of a hierarchical estimation method for anthropometric variables”, International Journal of Industrial Ergonomics, Vol. 35 No. 4, pp 331-343.